Extension of the study to CC grown by different methods

Home

Help

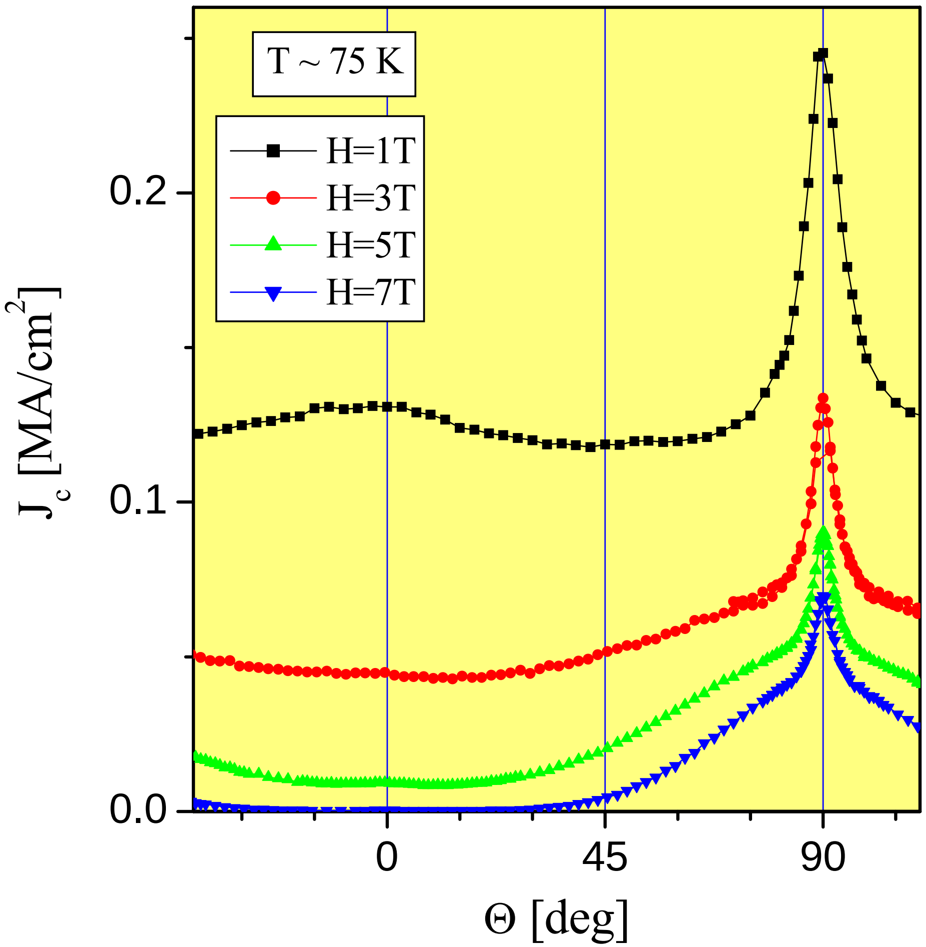
Summary

Plan # 3 for FY 2004:

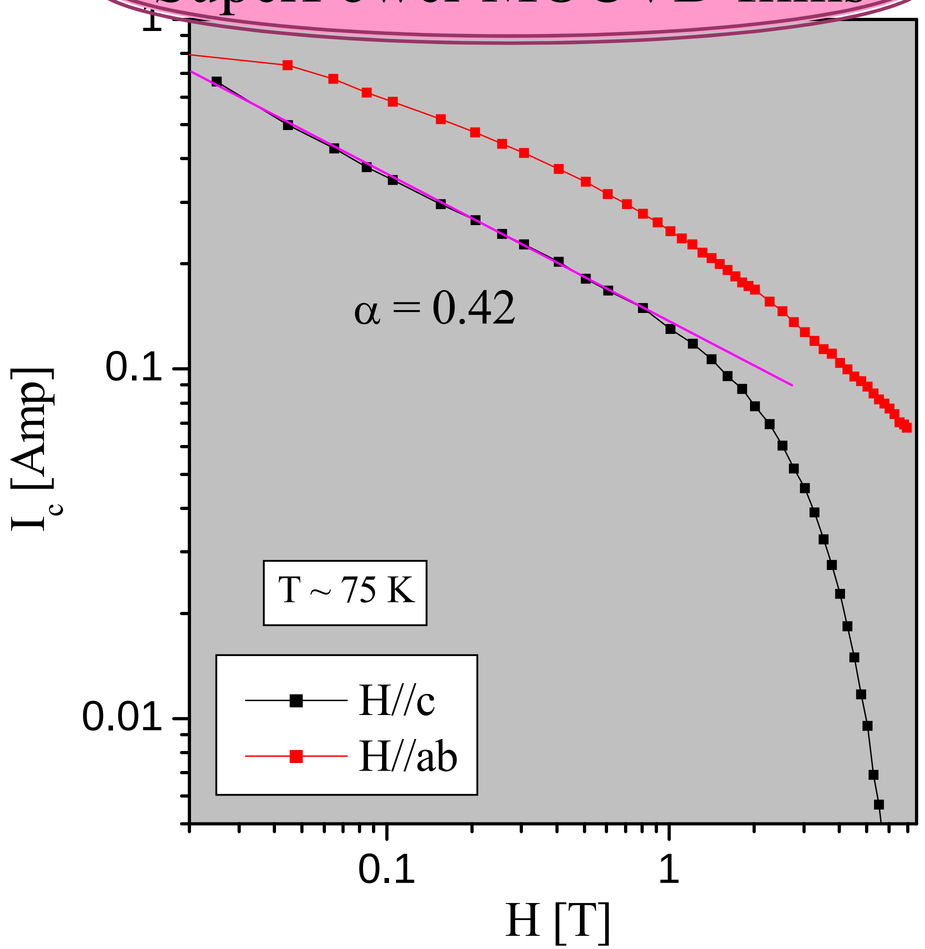
- To explore the angular dependence of J_c in CC with different architectures.

  Goal: to determine how the relative importance of the pinning mechanisms identified in PLD/IBAD MgO changes depending on the microstructure.

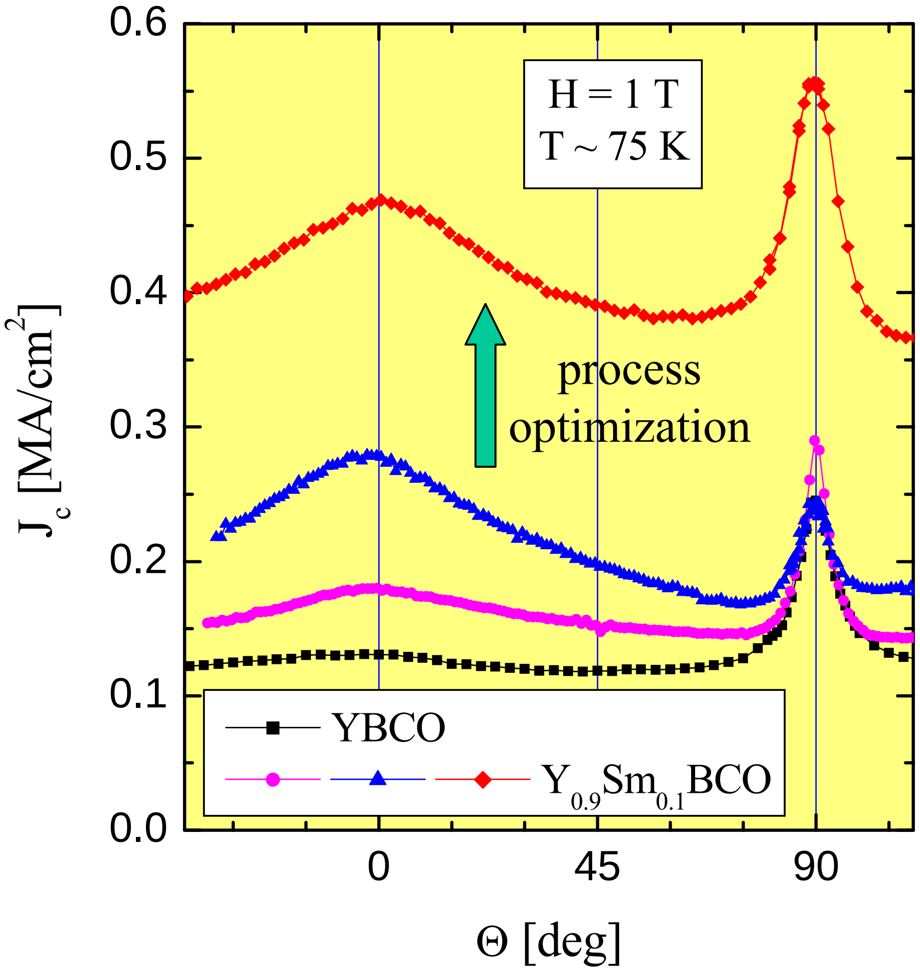
J_c (Θ) in "standard" YBCO MOCVD films on IBAD shows both a c-axis peak and a correlated ab-plane peak

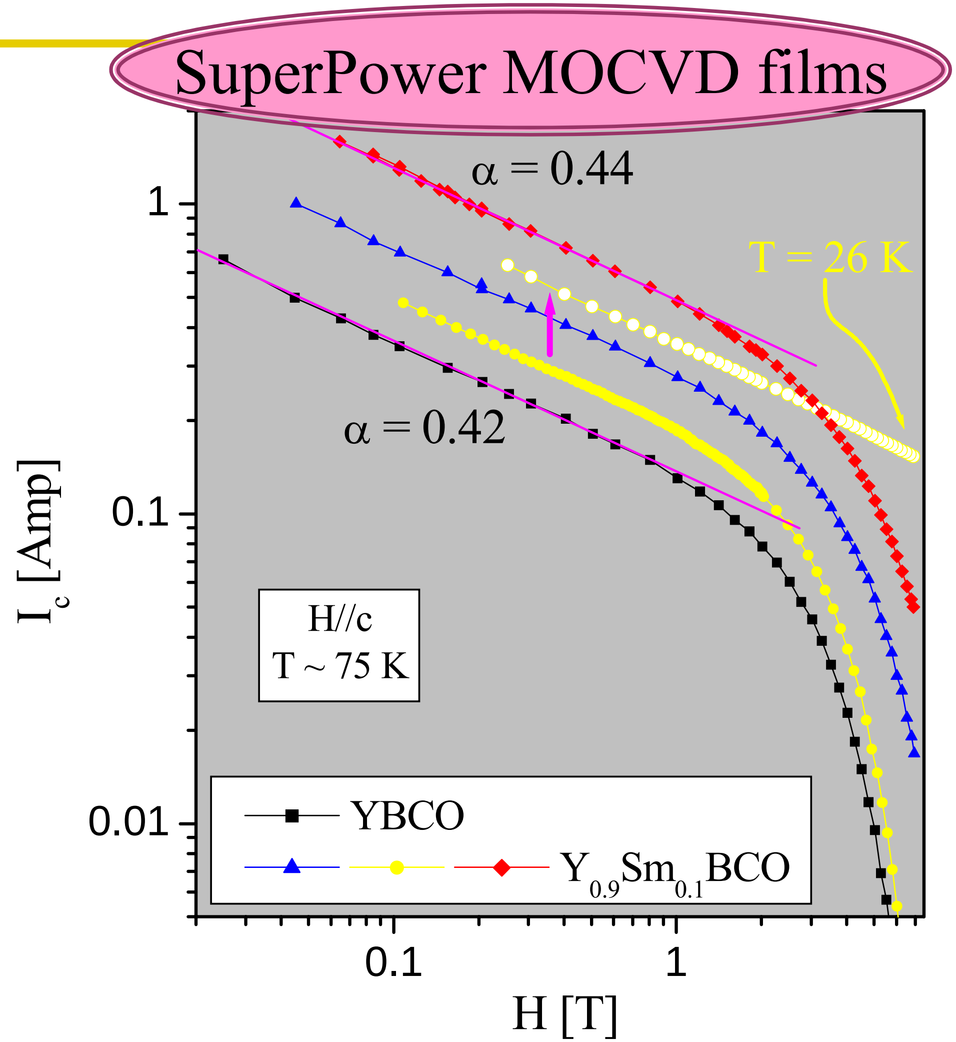


SuperPower MOCVD films

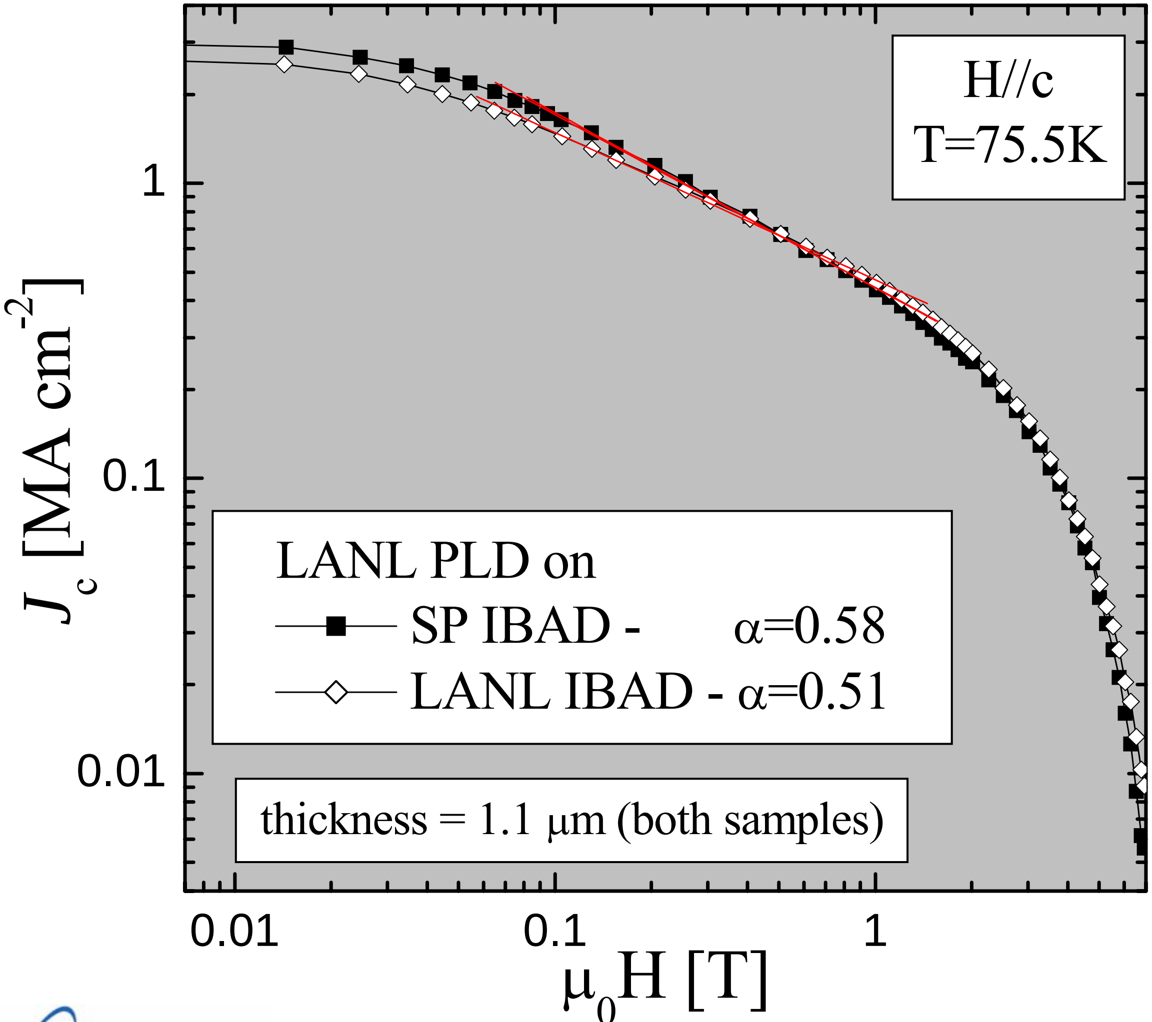


Large J_c improvements are obtained by Sm doping. Huge c-axis peak, but same α as in YBCO



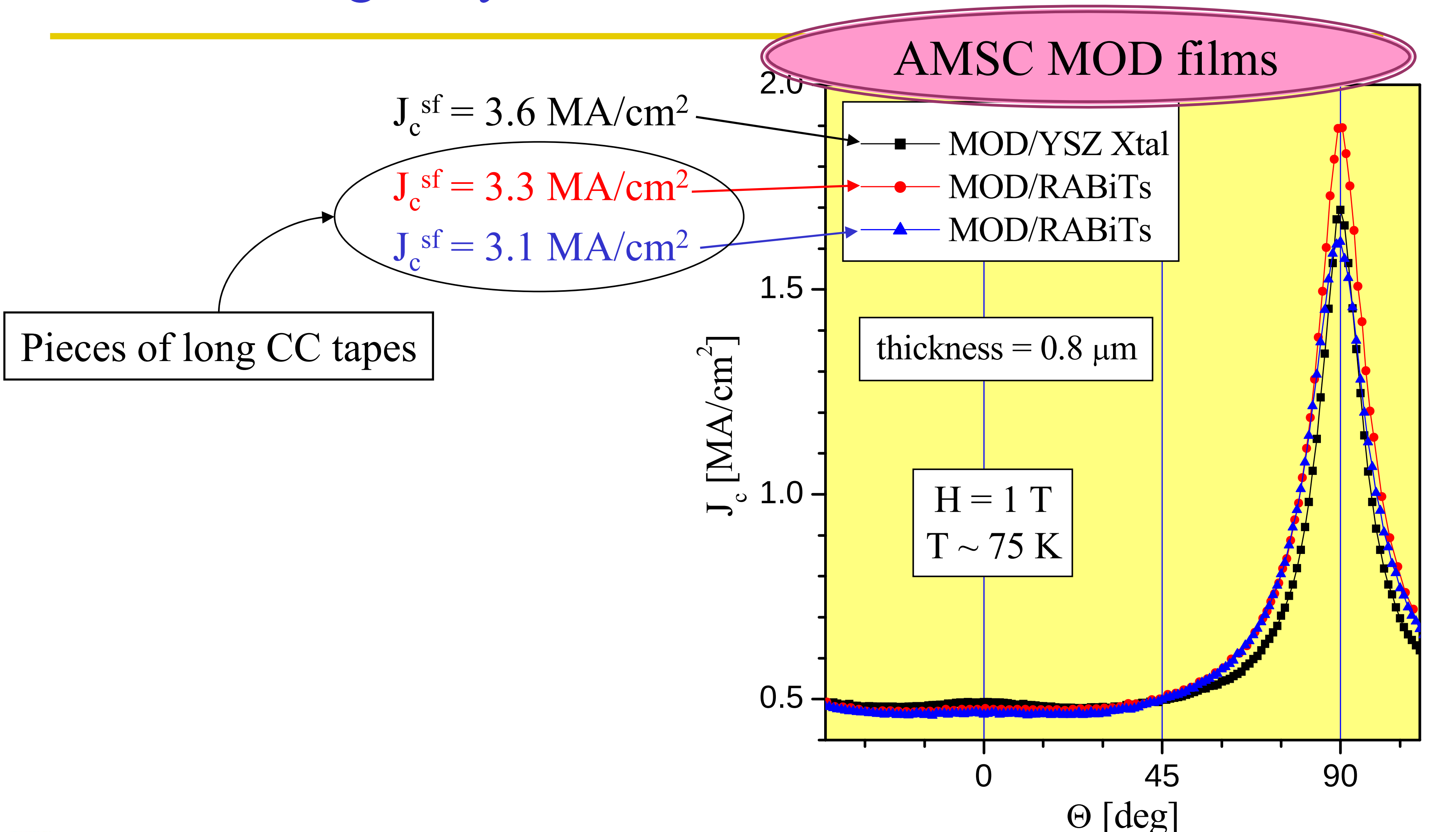


LANL PLD YBCO on Superpower IBAD MgO: very similar to equivalent "all LANL" samples

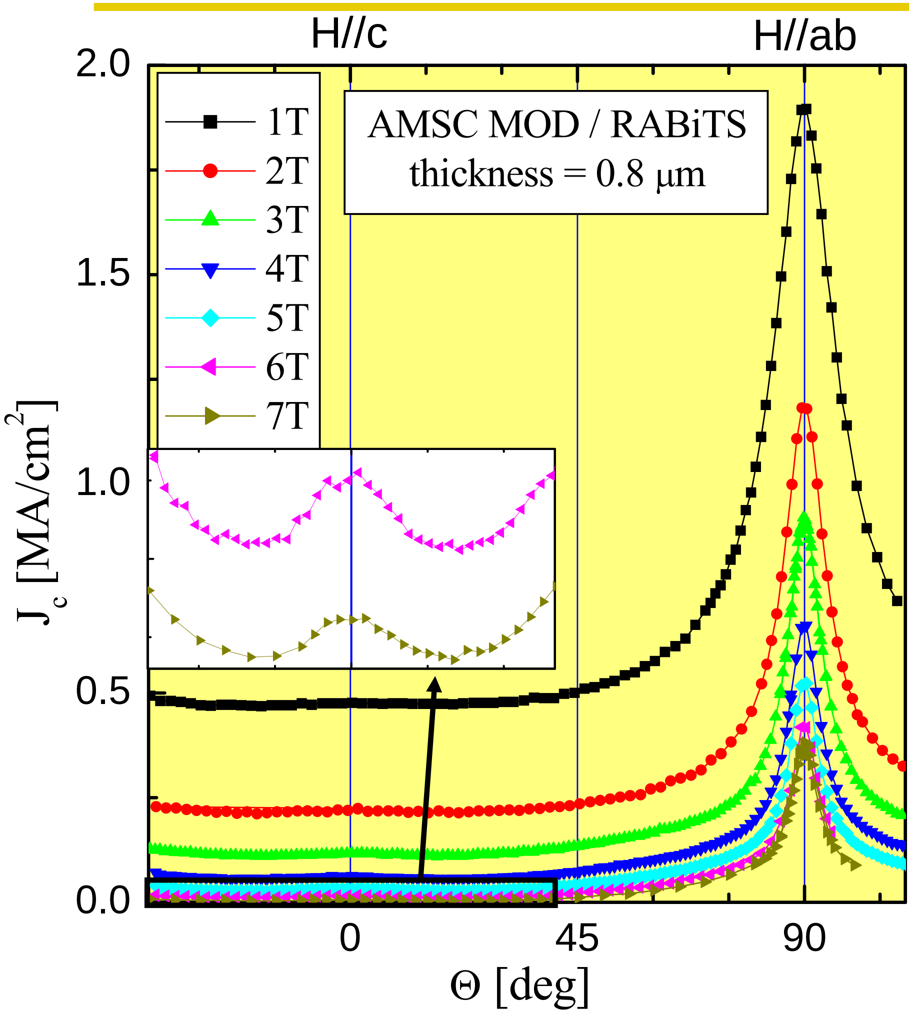


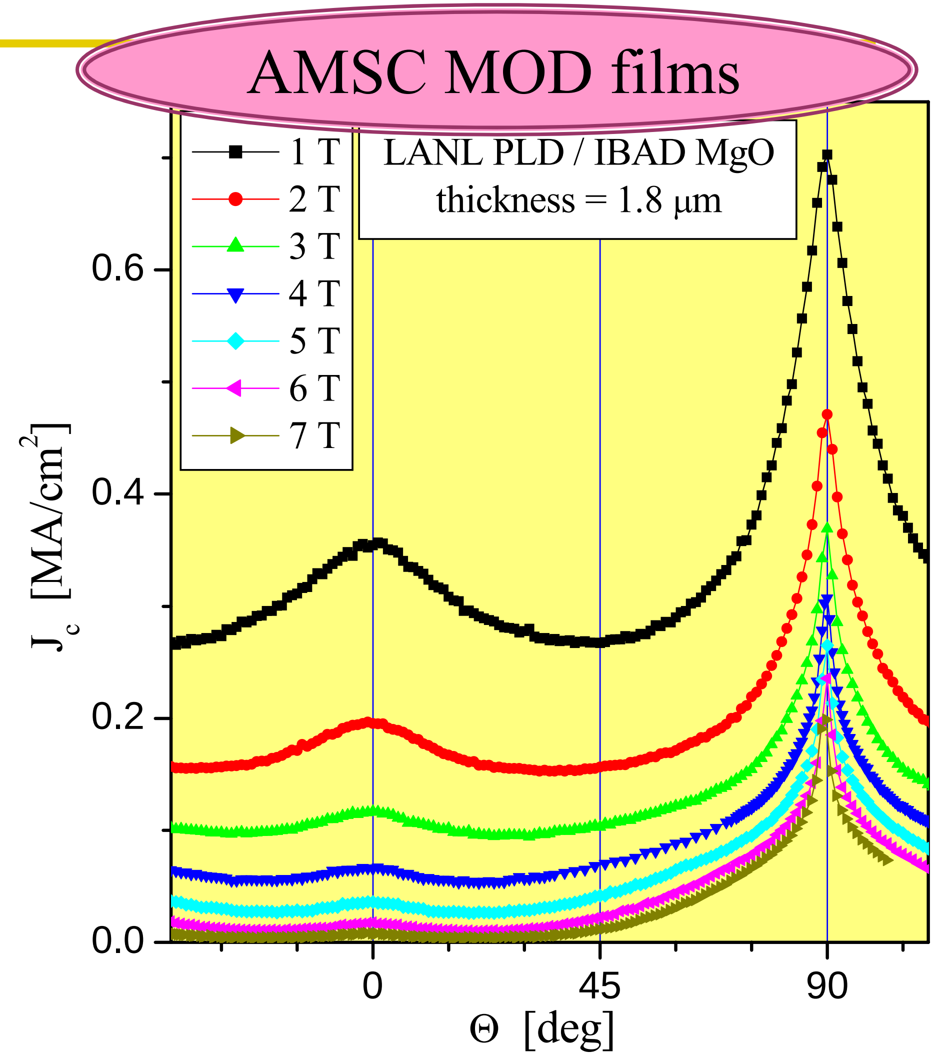
robustness / maturity of the technology

$J_c(\Theta)$ is reproducible, and similar for MOD films on single crystal substrates and on RABiTs



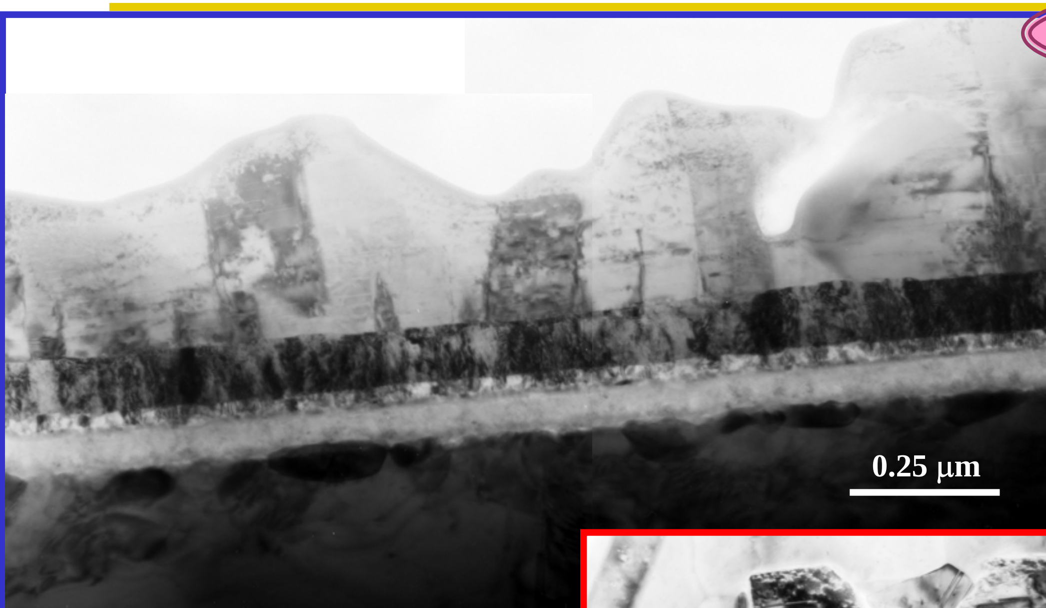
PLD: large c-axis peak, small ab-plane peak
MOD: small c-axis peak, large ab-plane peak



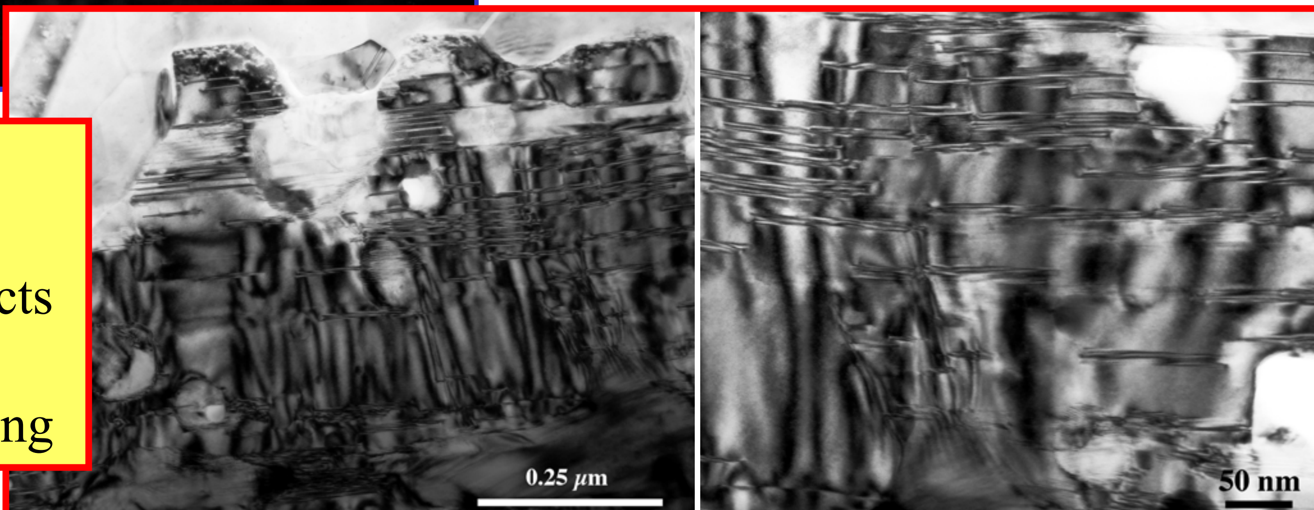


Pinning differences between MOD and PLD films clearly correlate with structural differences

AMSC MOD films



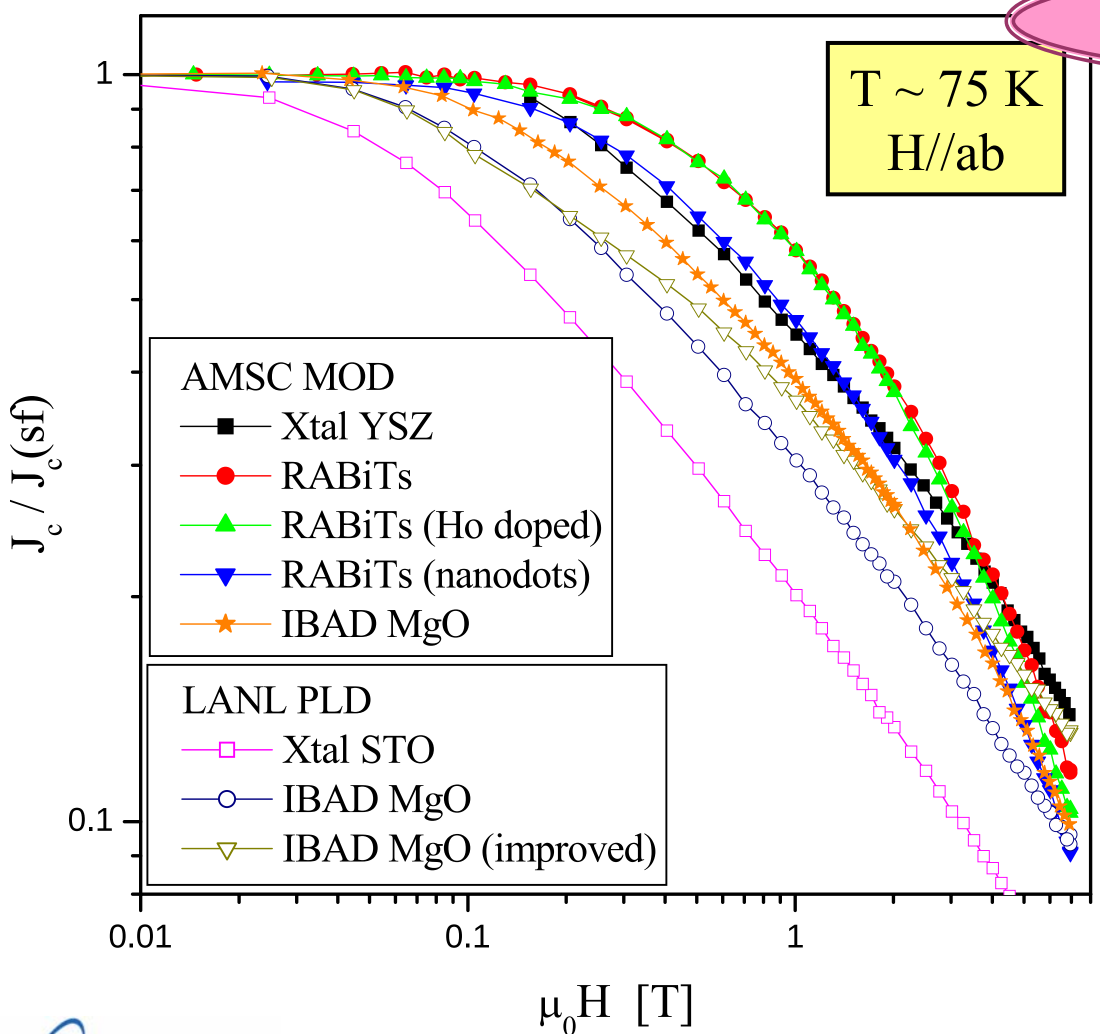
PLD:
- columnar growth
- c-axis correlated defects (dislocations)
- enhanced c-axis pinning



MOD:
- laminar growth
- ab-plane correlated defects (stacking faults)
- enhanced ab-plane pinning

Field dependence of J_c for H//ab: better in MOD than in PLD due to larger density of correlated defects along ab-planes

AMSC MOD films



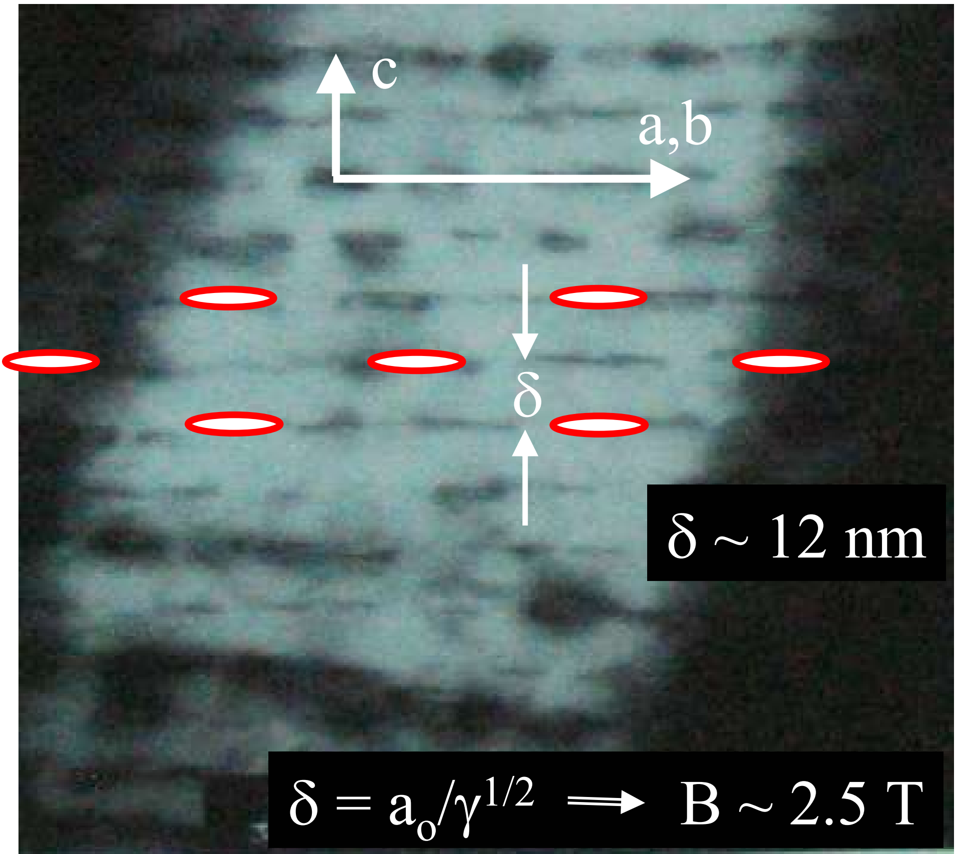
in contrast, field decay of J_c for H//c is faster in MOD due to smaller c-axis peak, α ~ 0.7

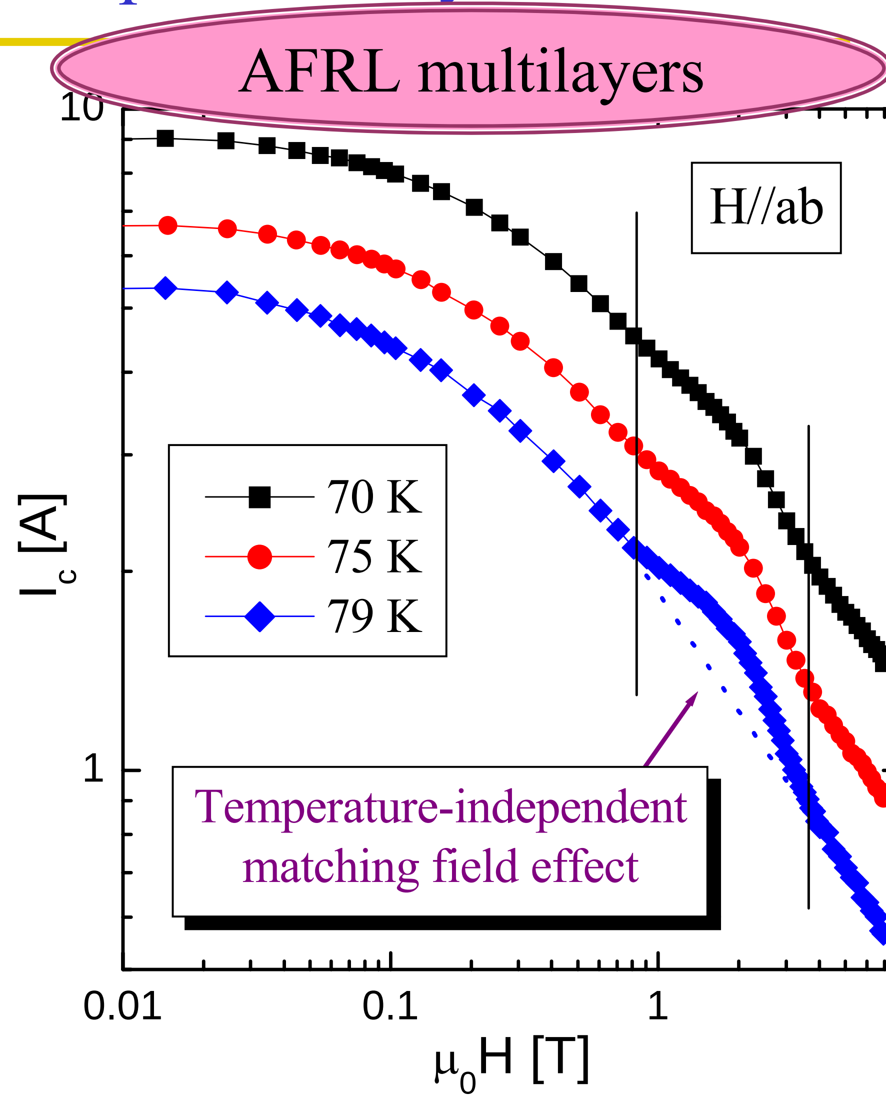
nanoparticle doping in MOD improves α to ~ 0.6.

What happens if the correlated defects along the ab planes are distributed periodically?

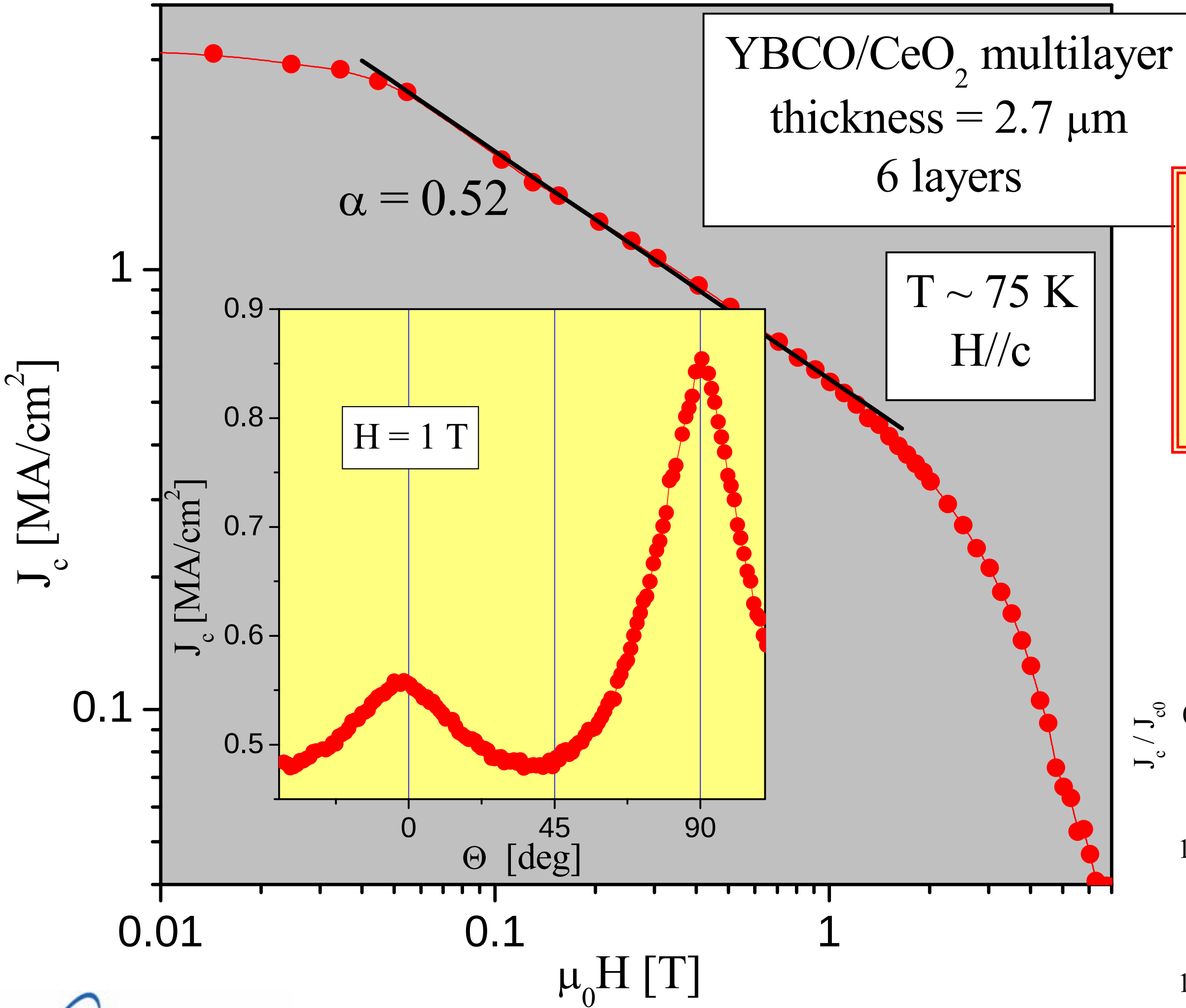
Y-123 / Y-211 multilayers

(T. Haugan & P. Barnes, Air Force Res. Lab.)





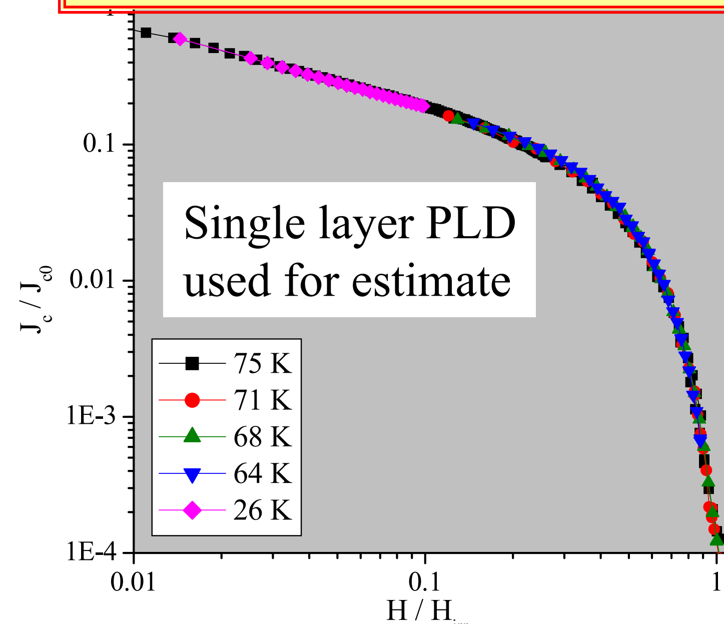
YBCO/CeO_2 multilayers: world record I_c, up to 1400 A/cm
$J_c(H,\Theta)$ similar to PLD YBCO single layer (in progress)



This sample:
I_c(75K,sf) ~ 880 A/cm

IF J_c(H//c,T) scales similarly to single layer PLD, THEN

I_c (50K, 3T) ~ 570 A/cm



Scoring criterion – Results

1. In PLD YBCO films, the angular range of influence of correlated pinning mechanisms (both along the c-axis and ab-planes) increases with decreasing temperature. In particular, at T ~ 26 K they are active for all field orientations.

2. J_c for H//c can be scaled over wide ranges of H-T. This allows us to predict J_c values for arbitrary (H,T). The technologically relevant regime for H//c exhibits a power law dependence $J_c \propto H^{-\alpha}$ (α~0.6). The range of this "low field" regime increases with decreasing temperature, exceeding 7 T at 26K.

3. Several successful routes to nanoengineer defects to enhance pinning demonstrated.
   - ⇒ simple, inexpensive and scaleable technique ablating YBCO and $BaZrO_3$. This yields $BaZrO_3$ nano-particles and extra c-axis dislocations.
   - ⇒ small but non-zero RE ion size variance in mixed RE compositions (random defects) .
   - ⇒ mixed RE's which contain Y and Sm (random and correlated defects).
   - ⇒ lower growth temperature of buffer producing surface particles which cause a-b planes to tilt and result in low angle grain boundaries parallel to 'c'

Scoring criterion – Results (continued)

4. PLD YBCO/CeO_2 multilayers with record high Ic (up to 1400 A/cm) exhibit similar field and angular dependence of Jc as single layer PLD YBCO.

5. The laminar growth associated to MOD results in a large density of planar defects parallel to the ab-planes, which dominates pinning in a wide angular range and produce a better field dependence for H//ab. Large $\alpha \sim 0.7$ for H//c consistent with the small density of c-axis correlated defects.

6. MOCVD / IBAD exhibits very large c-axis peak and associated small $\alpha \sim 0.4$. Consistent with 3D island growth and proliferation of c-axis correlated defects.

7. The discontinuous Y211 layers in YBCO/Y211 multilayers act as a periodic extended planar defects parallel to the ab-planes and produce a tunable matching pinning effect.

Scoring criterion - Performance

- To extend transport measurements and analysis to lower temperatures. *Goal: to identify pinning sources and angular regimes in the temperature range $75\ K < T < 26\ K$ (liquid Ne).*

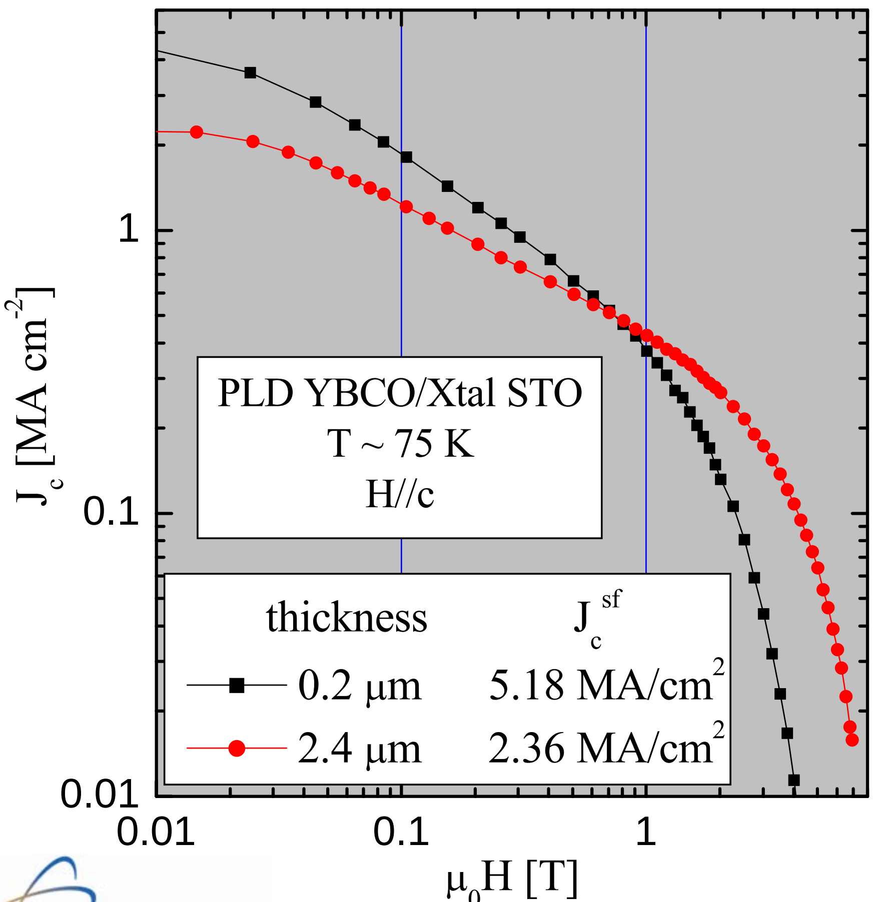
✓ We performed studies of $J_c(H,\Theta,T)$ in large number of PLD films on single crystal and IBAD MgO substrates.

✓ We developed H-Θ-T phase diagrams for the pinning regimes and found scaling rules for $J_c(H,T)$.

✓ We extended these studies to samples provided by our partners

Scoring criterion - Performance

- To extend the study to films thinner than 1 μm. *Goal: to determine whether the main pinning sources in those films with J_c > 4 MA/cm² are still the same.*



✓Measured several YBCO PLD/Xtal STO films in the 0.2 μm to 1 μm thickness range.

Overall they have similar angular dependence as thicker films, indicating same pinning regimes…

…but Jc decays faster with field (lower irreversibility line).

Scoring criterion - Performance

➢ To explore the angular dependence of J_c in CC with different architectures. *Goal: to determine how the relative importance of the pinning mechanisms identified in PLD/IBAD MgO changes depending on the microstructure.*

We studied:

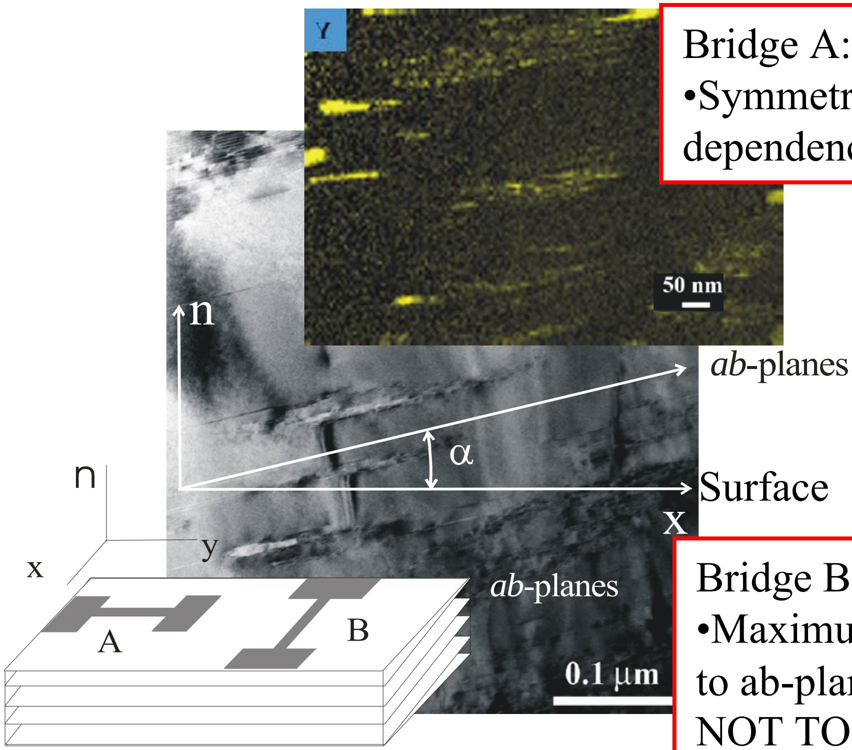
✓ SuperPower pure YBCO and Sm-doped MOCVD on IBAD.

✓ AMSC pure YBCO, Ho-doped, and nanoparticles-doped MOD on both RABiTS and single crystal YSZ.

✓ AFRL YBCO/Y211 multilayers.

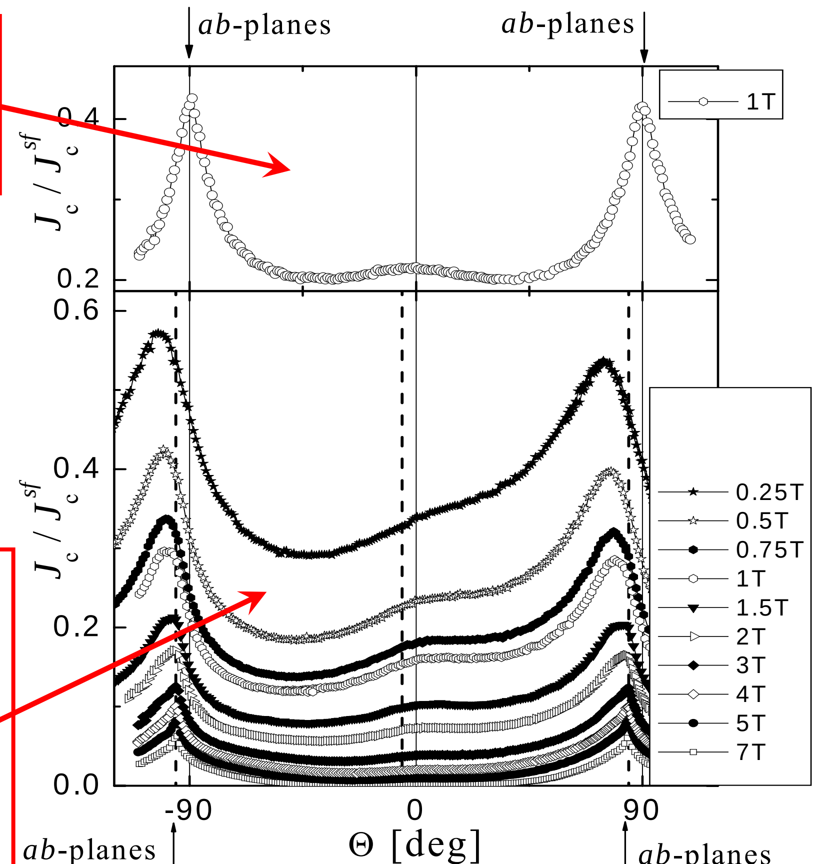
Scoring criterion - Performance

- To perform J_c measurements with current flowing in different directions in the plane. *Goal: to explore the in-plane anisotropy of the c axis correlated disorder, to determine whether the defects are linear or planar*.



Bridge A:
•Symmetric angular dependence

Bridge B:
•Maximum parallel to ab-plane (Θ=85°), NOT TO surface.
•Asymmetric angular dependence



B. Maiorov et al., unpublished

Scoring criterion - Performance

- To grow HTS films with rare earth substitutions. *Goal: to search for pinning enhancements by introduction of random defects.*

✓ We explored a large variety of RE substitutions in films on single crystal substrates and on IBAD MgO.

✓ We investigated pinning in samples with RE substitutions produced by our industrial partners.

Scoring criterion - Performance

- To introduce columnar defects at different angles in YBCO films on single crystal substrates. *Goal: to measure angular dependence of J_c in samples with a controlled defect structure, for comparison with the CC.*

This goal was modified, as we found several practical ways to introduce correlated defects in different orientations, and we obtained samples with periodic correlated disorder from our partners. This includes

•Epitaxial $BaZrO_3$ nanoparticles in YBCO PLD films that generate c-axis correlated defects

•211 layers in YBCO/211 multilayers from the AFRL that act as a periodic pinning structure of planar defects along H//ab, and produce a temperature independent matching field effect.

•Inclined IBAD MgO templates produce tilted correlated defects (see goal #3 above).

•DyBCO films on Xtal STO show asymmetric angular dependence with respect to H//c, with a tilted peak centered at a field dependent angle $\Theta \neq 0$. Evidence of tilted correlated defects, similar to vicinal substrates, but our substrates have no miscut ($<0.2^0$). (Topic not covered).

Scoring criterion – Research integration

- About 10 MOCVD/IBAD CC from SuperPower were measured, including samples with Sm-doping and/or other pinning enhancement approaches.
- About 10 MOD/RABiTS CC from AMSC were measured, including samples with nanoparticles and with Ho-doping. Incorporation to WDG.
- Combined samples:
  - SuperPower IBAD on LANL buffers & YBCO.
  - AMSC MOD on LANL IBAD MgO.
- Collaboration with AFRL on studies of YBCO/211 multilayers.

Scoring criterion – FY2005 plans

- Continue to study pinning enhancement by nanoparticles, RE substitutions (variance), and YBCO/CeO_2 multilayers (coordinated with S. Foltyn et al.). *Goal: 1000 A/cm at 40K, 3T.*
- Extend angular dependent measurements to non-maximum Lorentz force configurations. *Goal: understanding of pinning and current distribution in realistic situations for applications.*
- Improve our liquid Ne (26K) measurement capabilities. *Goal: 5 fold throughput increase.*

We also expect to continue to study flux pinning in CC from our industrial partners.